Synchrotron Radiation Instrumentation
Collaborative Access Team

SRI CAT NEWSLETTER

Vol. 2, No. 4 April 1996

From the desk of the Executive Director:

Considerable progress has been made on the commissioning activities of the SRI CAT beamlines. During the last run, which was in January, 1-BM and 1-ID both accepted radiation into the A and B stations, and the required shielding verifications were performed with sizable stored beam currents (>20 mA). This was an important measurement, since most of the stations being constructed by other CATs are identical in shielding specifications to those of the SRI CAT. A few minor leaks around the seams between the doors and wall/floor were detected, but in general the shielding proved to be satisfactory. The 3-ID beamline also received radiation for the first time into Station A. Several trips of the Personnel Safety System (PSS) cut into our commissioning plan on all beamlines. Nonetheless, one significant milestone was met on the last day of the January run when, with 100 milliamperes of stored beam, the undulator on 1-ID was closed to 11.5 mm, the minimum magnetic gap. Radiation was then allowed to enter the 1-ID First Optics Enclosure (FOE or Station A) and the commissioning filter/window assembly was tested. (Nothing melted!) Needless to say, a full agenda of commissioning activities are planned for the next running period scheduled to start in late March, including first beam from the 2-ID line.

Another important event has also occurred since the last newsletter, namely the addition of Australian members into the SRI CAT. This participation was formalized on January 17, 1996, when a memorandum of understanding (MOU) between the Australian Nuclear Science and Technology Organization (ANSTO), representing the Committee of Management, Australian National Synchrotron Beamline Facilities and the Advanced Photon Source was penned. Dr. Helen Garnett, Executive Director of ANSTO, Dr. John Boldeman, Manager and Coordinator for the Australian Synchrotron Research Program (ANSTO), Dr. Richard Garrett of ANSTO, and Professor John White from the Australian National University were present at the MOU signing along with representatives from the ANL, APS, and SRI CAT management. The agreement calls for the Australian scientists to become Developers and to contribute financially to the construction and operations of the SRI CAT beamlines. In addition, a postdoc, hired by the Australian team, will be stationed full time at the APS to help with the construction, commissioning, and operation of the beamlines and to assist Australian visiting scientists when they arrive at the APS to perform experiments. All the members of the SRI CAT would like to welcome the Australian participants in our Collaborative Access Team. We look forward to many fruitful professional and personal interactions.

Finally, I would like to thank Patrick DenHartog, Chairman of the SRI CAT Safety Committee, and all the other members, Vladimir Kushnir, Dan Legnini, Al Macrander, and Mohan Ramanathan, for taking our safety plan from paper to practice over the last several months. This is a particularly difficult task at this juncture in time since things are changing so fast during construction and commissioning. Keep up the good work.

D. Mills, Executive Director, SRI CAT

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SRI CAT Time-Resolved Studies

Introduction

X-ray scattering and spectroscopy techniques are well known for their ability to provide detailed structural information about a wide variety of materials of both scientific and technological interest. Using high brilliance x-ray sources, high throughput optics, and fast parallel-detector technology, it is possible to perform these measurements on increasingly short time scales. These developments have laid the foundation for the field of time-resolved x-ray studies, where rapid sequences of scattering or spectroscopy measurements are performed to monitor structural changes in materials as they occur, often in real time.

For example, wide bandpass monochromators and fast linear array detectors have been used to make *in situ* time-resolved diffraction measurements of the kinetics of phase transformations in metal alloys, silicides, and glasses, with a time resolution down to several milliseconds [1-3].

Such measurements provide insight into the physical processes that mediate these transformations and have been used to study short-lived transient structures, which only exist far from thermodynamic equilibrium. The techniques have also been used to develop and refine processing strategies for forming technologically important and novel materials [2,4].

The field of time-resolved x-ray studies has grown tremendously in the last 15 years. Broadly speaking, the techniques can be classified into three groups. The first is "stop-action" studies, where samples are quenched or "frozen" after various degrees of evolution and analyzed with *ex situ* techniques. The time-scales for study are then limited only by how quickly the evolution can be halted, and care must be taken to account for possible changes during the quench. The second group is that of stroboscopic measurements, where the sample is excited in a pulsed or periodic fashion, and the x-ray illumination and/or detection scheme is synchronized to the excitation. By varying the time-lag between the excitation and the x-ray measurement, it is possible to map out the system's response to the excitation. These stroboscopic techniques have been used to obtain time-resolution in the nanosecond regime [5]. A closely related technique is used in nuclear resonant scattering, where the synchrotron pulse *is* the excitation.

The third category is that of real-time studies, where sequences of scattering or spectroscopy measurements are made *in situ* to map out the structural evolution as it occurs. Such measurements commonly have a time resolution ranging from seconds to milliseconds. The focus of the SRI-CAT time-resolved program is on real-time studies including both spectroscopy and scattering, with capabilities extending to the microsecond range.

Overview

Many time-resolved techniques benefit from the use of dispersive or wide-bandpass x-ray optics.

To this end, we are currently developing both dispersive curved-crystal optics and wide bandpass multilayer optics that can operate under the large power loads produced by the x-ray sources at the APS. We are building a dedicated station at the APS bending magnet beamline 1-BM (Figure 1) where our horizontally focusing curved-crystal monochromator will be implemented for dispersive time-resolved studies. The time-resolved station, 1-BM-B, can accept white or pink beam from the source such that time-resolved Laue measurements are also possible. Although 1-BM-B is dedicated to these studies, we will also have the use of the insertion device beamline 1-ID, when higher brilliance beams are required.

The detectors to be used at this facility are primarily those developed by the SRI-CAT detector program. This group is developing fast x-ray detectors for specialized single-channel, linear-array (1D) and area-detection (2D) applications, as described in the subsequent article. Those detectors being constructed in support of our time-resolved studies are highlighted below.

One of the most important experimental challenges for time-resolved measurements, particularly as they are pushed to ever shorter time scales, is to develop methods for rapidly changing and monitoring the state of the specimen in a controlled and uniform manner. In this regard, we are devising sample cells that permit abrupt, controlled, and reproducible thermal changes, and that are appropriate for both transmission and reflection geometries.

Finally, we are actively involved in studies with coherent beams of hard x-rays. Because the scattering pattern formed with a coherent incident beam is sensitive to the *specific* arrangement of disorder in a material (as compared to the *spatially averaged* degree of disorder), such studies have opened the possibility of studying the time structure of *equilibrium* fluctuations in disordered materials, such as the large amplitude thermodynamic fluctuations that exist near structural phase transformations. This is in contrast to most other time-resolved x-ray techniques, which typically measure the evolution of a system following a perturbation to its thermal equilibrium (e.g., laser pulse, temperature step, pressure jump, etc.). We will discuss our work in this area in a future article.

Time-Resolved Experimental Station

Figure 1 shows a schematic of the first two stations on our beamline and the two principle modes of operation. Both modes make use of a vertically collimating mirror with a critical energy of 24 keV. In the first mode, pink beam is admitted to the time-resolved studies station, 1-BM-B. In the second mode, the double-crystal Si monochromator in 1-BM-A is implemented, to provide sagittally focused monochromatic radiation to the downstream station 1-BM-C (not shown). In the first mode, the key instrument within the time-resolved station is the curved-crystal monochromator. As shown in Figure 1, pink beam incident on the curved crystal is focused to a point within the 1-BM-B station. Beam exiting the monochromator will pass through custom slits designed to reduce unwanted scattered radiation and a 0.55-m long mirror that will reject harmonic radiation when required. The sample cell and detector will typically be mounted on a 4-circle goniometer with the specimen at the monochromator focus.

Station 1-BM-B is large enough to permit a large range of operating focal lengths and energies. Monochromator-to-sample distances in the range 0.75-

4.0 m and an energies range of 5-16 keV can be attained using a Si(220) monochromator crystal. Because the sample cell, goniometer, detector system, beam monitors, and harmonic-rejection mirror will need to be repositioned within the station for each change of energy or focal length, we have decided to mount all this hardware on the four-circle goniometer table. All the hardware can then be repositioned at once, to within small motorized corrections.

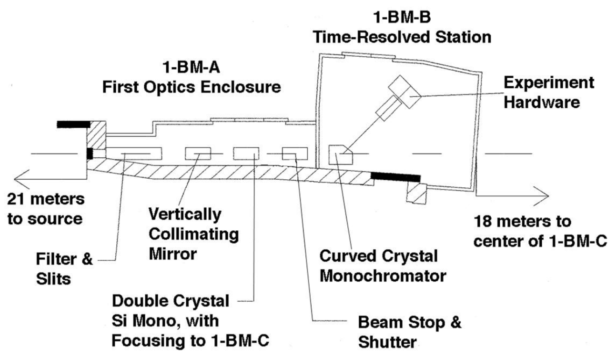

Fig. 1. Sketch of the first optics enclosure and the dedicated time-resolved scattering station on the1-BM beamline.

The table will be relocated by lifting it on air pads and moving it until three different mechanical constraints between the table and the station perimeter are drawn taut, the length of each constraint having been calculated to give the desired table position and orientation. The mechanical constraints will then be removed and fine motorized adjustments made after the table has been leveled in the new position.

Optics Development

Our foremost optics development effort has been the design and construction of a versatile monochromator for dispersive studies. Such a monochromator must provide adjustability of energy (E=5-24 keV) and energy bandwidth ($\Delta E/E=10^{-4}$-10^{-1}) in addition to a strong correlation between angle and energy in the focused beam. This may be effectively achieved through the dynamic elastic bending of a flat perfect crystal. The average x-ray energy transmitted by the curved-crystal monochromator is determined by the average Bragg angle, and the bandwidth is varied by changing the average radius of curvature (which also changes the focal position). The ideal surface figure of the bent crystal is an elliptical section that has the source at one focus and the experiment (specimen) at the other. The requirements for accuracy and stability of the figure place stringent demands on the mechanical integrity and reproducibility of the bender mechanism. At the APS, these challenges are exacerbated by the high power (≈90 W per horizontal milliradian at 100 mA) and power density on the crystal. The design must provide uniform and high cooling power while still permitting fine crystal deformations. This is particularly challenging because any rigid mechanical contact with the crystal, apart from the bending points, will disrupt the figure.

A four-point bending scheme was selected (Figure 2) to give the best approximation to the desired elliptical figure. The crystal has dimensions of 355 x 32 x 0.8 mm^3. When located 32 m from the source, the monochromator is designed to collect 3.1 mrad of bending magnet radiation and focus it to a horizontal spot <100 µm in size. Our cooling scheme is to submerge the lower half of the crystal in a bath of Ga-In-Sn-Zn alloy, which thermally couples the crystal to the water-cooled Cu frame. This alloy was chosen because it remains liquid down to ≈8 °C. The x-ray beam will strike the crystal 3 mm above the surface of the Cu frame and the liquid-metal meniscus. This scheme permits the required crystal deformations, while providing nearly uniform cooling along the length of the crystal. Finite element thermal analysis predicts a thermal gradient of <10 °C over the vertical FWHM of the beam under typical operating conditions [6].

In order to perform time-resolved dispersive x-ray absorption fine structure (XAFS) measurements, an energy-dispersed beam with a bandwidth of $\Delta E/E \approx 0.1$ is required, with a strong correlation between angle and energy, and the smallest possible spot size. We estimate that the curved-crystal monochromator on 1-BM will provide the required bandwidth over the energy range of 5-16 keV using a symmetric Si(220) crystal. For a typical detector configuration, the resolution will be ≈2 eV and the focal spot < 100 µm. These conditions will be adequate to produce high quality XAFS spectra.

For angularly dispersed, monochromatic studies, an asymmetrically cut monochromator crystal is selected such that the dispersion from the asymmetric cut cancels that from the variation in Bragg angle along the crystal. The resulting beam then has an energy bandwidth nearly equal to that of a flat monochromator of the same crystal reflection but provides a relatively large angular fan of radiation at the focal point (approximately equal to the angular range that the monochromator accepts from the source). Such an angularly dispersed beam has application in time-resolved studies of single crystals, as we will describe shortly.

Other optics being developed within our group include integrally cooled wide-bandpass multilayer optics for hard x-ray applications. Such optics may be used, for example, in time-resolved diffraction experiments, where relatively low energy resolution (approximately 1%) and high flux at the sample are desired. Work is underway to fabricate SiC substrates with integral cooling channels, on which multilayers could be deposited that would perform well under the power loads of APS undulator A. The substrates will be formed by a proprietary pressure-casting technique and will be coated at the APS deposition facility.

We also have a long-term interest in beam choppers for modifying the natural time structure of pulses from the storage ring. We have several designs in hand, which could be constructed for selecting an isolated x-ray burst from the storage ring. However, work has been deferred in this area until optimal bunch structures for running the APS storage ring have been determined.

Detectors

Fast x-ray area detectors based on CCD arrays are being developed for time-resolved applications, including

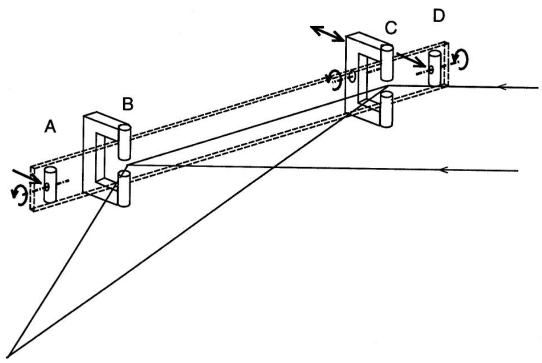

Fig. 2. Schematic representation of the 4-point bending scheme. The positions at which the crystal is constrained are labeled A, B,C, and D.

small-angle scattering, Laue diffraction, and time-dependent scattering with coherent x-ray beams. In particular, a data acquisition system using a large fast memory has been devised (256 Mbytes/channel, 16 bit data accepted at a clock rate of 20 MHz) that will permit the acquisition of 512 x 512 images in as little as 10 ms per frame. This system can be configured to work with a variety of CCD chips. A variety of optics can be implemented for imaging x-ray phosphor screens onto the CCD.

Fast linear detectors, which make use of CCD chips in a streak camera mode, are also under development. Here, all but the top few rows of the CCD are masked from x-ray illumination. Because CCD chips are typically read out by downward row shifting, with a serial readout of the last row, it is possible to use the masked portion of the CCD as a storage device. In this way, it will be possible to form a 1-D detector with a time-resolution of ≈10 µs for a total of approximately 500 exposures. If longer sequences of exposures are required, the device can be configured for continuous readout, with a slower time resolution of several hundred microseconds.

Experimental Plans

With assembly of the crystal bender and monochromator anticipated soon, we expect to be commissioning these and other in-station hardware through the spring of 1996. This will include testing the bender mechanism and its cooling system, developing focusing schemes, and measuring both the focal spot size and energy-angle correlation in a dispersed beam. The performance, reliability, and stability of the apparatus will be assessed by performing static EXAFS and dichroism measurements in a dispersive transmission mode.

Initial time-resolved experiments will include fast dispersive x-ray absorption spectroscopy, using the CCD streak camera. These measurements will offer the capability of studying both structural and chemical changes on microsecond time scales. We are also planning dispersive diffraction studies of phase transformations in single crystals. Here, the curved-crystal monochromator will be used to form a monochromatic but angularly dispersed beam. A position-sensitive detector can be used with such a beam to collect a pure radial scan in reciprocal space, without the need for moving the specimen. This geometry will be useful for investigating rapid structural changes in single crystals.

We are also excited by the possibility of making simultaneous measurements of both transmission absorption spectroscopy and wide-angle scattering. The idea is to use a pair of linear detectors to record both the transmission absorption spectrum and vertical wide-angle scattering from a material as it undergoes a phase transformation. This will be suitable for studies of reactions in polycrystalline materials in which the diffraction signal will be dominated by the 1-2% bandwidth of energies below the absorption edge. By correlating the locally averaged spectroscopy information with the more long range information provided by the diffraction, we hope to develop a more complete picture of structural transformation kinetics in oxide materials and relaxation phenomena in glasses.

In the longer term, we also hope to extend our capabilities for making rapid EXAFS measurements with small (≈100 µm) spot sizes to an imaging mode. Here the specimen will be rastered in two dimensions with a spectrum collected at each point. Analysis of the spectra will allow construction of an image with compositional and/or valence-state contrast. Such a technique could also be used in a time-resolved fashion. Applications to environmental research are envisioned, for example, in measuring the distribution of heavy metal contaminants in soils, sediments, and microorganisms used in cleanup operations.

Status Report

The first x-ray beam from the APS was observed on 1-BM in March 1995, and station 1-BM-B has recently been radiation-surveyed to permit white beam operations to 100 mA. The 1-BM-A mirror is scheduled for delivery in April 1996. Preliminary experiments are ongoing in the time-resolved station, using a temporary double-crystal monochromator in 1-BM-A. Most components for the crystal bender are in hand, including several 355 x 32 x 0.8 mm^3 crystals that have been prepared by our group. The curved-crystal monochromator will be assembled during March and April. The contract for the harmonic rejection mirror was recently awarded to Société Européenne de Systemes Optiques, with a six-month delivery date. The equipment positioning system is ready to be tested, once we complete the required software. *-S. Brauer, B. Rodricks, APS Experimental Facilities Division*

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The XFD Detector Development Program

An integral part of the scientific mission of the Time-Resolved X-ray Scattering Program is the development of high speed x-ray detectors. In addition to detectors in support of other time-resolved applications at the APS, we have been developing specialized detectors for applications within our own time-resolved research program. To foster the former, the APS has developed the Collaborative Research Program (CRP), whereby APS users and APS staff members pool their resources and technical expertise on R&D projects. Under the auspices of the CRP, the development of the Pixel Array Detector (PAD) was initiated with Prof. Sol Gruner of Princeton University and the CdTe photoconductor detector project with Pedro Montano of the Material Science Division at ANL and the University of Illinois. Since its inception about three years ago, the CdTe program has changed focus from high speed detection (10^{-10}-10^{-8} s) to include the development of high energy (30 - 120 keV) x-ray detection. In a related research program, we have also begun to investigate the possibility of coupling high energy x-ray converters to CCD front ends for two-dimensional imaging. Figure 1 illustrates the detector projects that we have undertaken. The detectors consist of CdTe and ZnCdTe photoconductors and photon-counting single pixel and linear arrays, a pixel array detector for high speed, limited-frame-number applications, and CCD detectors. In addition, we have initiated a program on microstrip gas detectors for large area imaging this year.

I. CdTe-Based Detectors

This program was initiated to develop a very high speed (nanosecond or better) detector. The detector consists of molecular beam epitaxially (MBE) grown CdTe. Having a wide band gap and a low intrinsic carrier concentration, this detector can be used effectively as a photoconductor. We characterized a single-pixel device for its resolution, sensitivity, noise, dynamic range, etc., using both laboratory-based x-ray sources, as well as synchrotron x-ray radiation [1]. The device has a temporal resolution of 21 ps, sensitivity better than a hundred 8-keV x-rays, and a dynamic range of 6000 at 230˚K .

Since the single-pixel measurements, this program has been expanded to include the development of a photoconductive linear-array device with moderate time resolution (MHz rate) and a device suitable for the detection of x-rays in the range from 30 to 150 keV.

A. CdTe photoconductive linear detectors: High crystalline quality MBE-grown (111)B CdTe was used to fabricate these devices on (100) Si substrates. This layer has a resistivity of 10^8 Ω-cm, whereas the Si resistivity ranged from 0.001 Ω-cm to 30 Ω-cm. A novel technique was developed to remove the epitaxial CdTe from the conductive Si and to mount it on an insulating substrate. Conventional lithography was used to fabricate the linear photoconductor array devices. The gaps between photoconductors were varied from 20 µm to 100 µm with a width of 50 µm. Two devices have been epoxied to ceramic substrates with one of them being microbonded to a commercial 5-MHz IR multiplexer that is ready to be tested. At the same time, growth of CdTe on a sapphire substrate has been initiated.

B. High energy CdTe detectors: Besides having a wide band gap, suitable for room temperature photoconductive operations, CdTe has high atomic number elements (48 and 52, respectively) that make it very efficient for absorption of high energy x-rays. The mission of this program is to develop a high energy detector suitable for energies up to 150 keV using bulk ZnCdTe. This material has a band gap of about 2 eV, which is excellent for room-temperature operations. A 1 cm x 1 cm x 1 mm device operating at 100 V in the photon-counting mode was tested on a high energy x-ray generator (225-KV tungsten tube). The quantum efficiency, when compared to a 50-mm NaI scintillator coupled to a PM tube, was measured to be 90% at 90 keV. The device displays excellent linearity over the current range from 1 to 8 mA. Fig. 2 is a $\theta-2\theta$ scan over the energy range of 30-100 keV using a 50-mm NaI scintillator coupled to a photomultiplier tube and a 1.0-mm ZnCdTe photon counting detector. Note that the plot is the very first measurement performed on the device that was not optimized in thickness or applied electric field for any particular energy and is undergoing further testing. Concurrently, an eight-pixel linear array that can be read out with hybrid preamplifiers, amplifiers, and discriminators is being fabricated. The fabrication of the linear device is straight forward, but the readout mechanism and techniques to minimize crosstalk need to be studied.

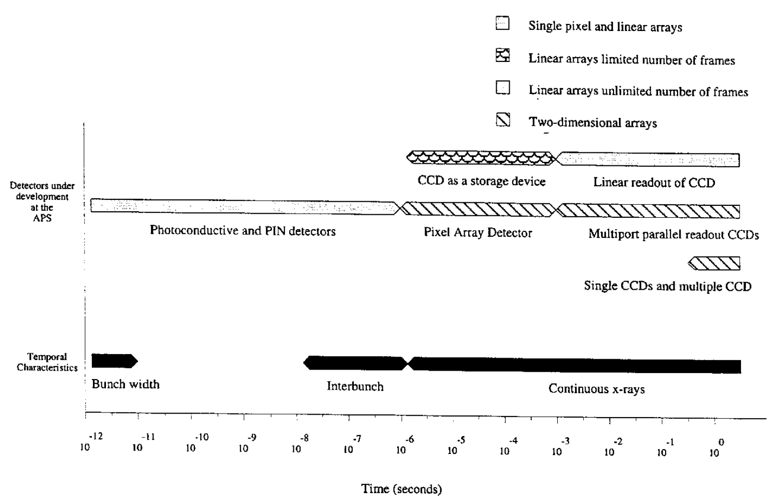

Fig.1. Plot of temporal characteristics of the APS vs. the detectors under development

II. Pixel Array Device Detectors

Because CCDs and most other two-dimensional detectors tend to use serial readout, there is a limit on their time resolution. But for a large-area, microsecond framing rate, no commercial device exists. The pixel array detector (PAD) was conceived as a hybrid device that allows one to store an entire array of data in parallel. The device consists of a diode array layer coupled to a storage bank layer. Each pixel has eight storage banks associated with it that allow up to eight frames of data directly on the device before it must be read out. The design goals of this device are:

- 1000x1000 pixels, each 150 µm square
- Detection and on-array storage of eight 1-5 µs full frame exposures
- 100% quantum efficient from 5-20 keV
- Radiation hard to 10^{15} photons/sec, 10^4-10^5 s lifetime for total dose
- Dynamic range of 80 dB
- Readout of eight frames of data in 0.05 s.

In addition to these design goals, the device should also have low storage droop rates for long integration and slow readout applications, and negligible frame-to-frame and pixel-to-pixel cross talk. The PAD consists of an x-ray-sensitive, fully depleted photodiode array bonded to a pixelated complementary metal oxide semiconductor (CMOS) electronics storage layer. During each framing period, the current resulting from the x-rays stopped in the diodes is integrated in the electronics layer and then stored in one of the eight storage capacitors fabricated in the CMOS layer underneath the pixel. These capacitors are read out when all eight frames of data are stored.

Three successive generations of the electronics storage layer were fabricated and tested. The devices were made using the 1.2 µm CMOS process offered by the MOSIS service of the Information Sciences Institute at the University of Southern California. They have a saturation level equivalent to 10,000 12-keV x-rays (corresponding to 45×10^6 electrons) with a noise corresponding to 2 x-ray photons. The readout per frame corresponds to a speed of 5 µs (frame rate of 200 KHz) [2]. A prototype diode on high resistivity (5000 ohm-cm) Si has been fabricated. The CMOS electronics layer and diode are currently being bonded. The development of the electronics necessary to read out the device, using techniques similar to those on the CCD project as described later, has been initiated.

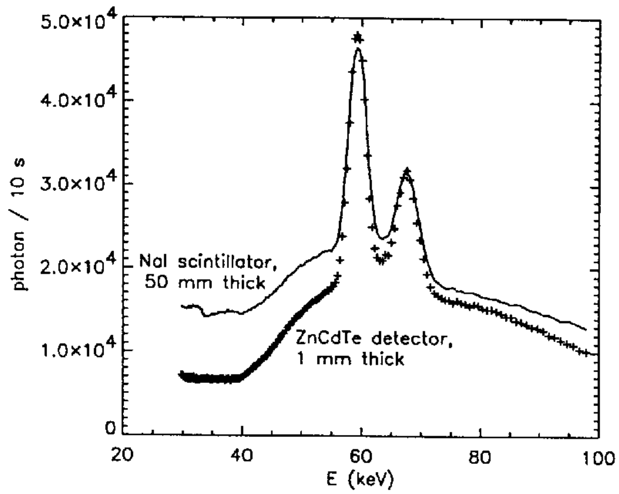

Fig. 2. θ–2θ *scan over the energy range of 30-100 keV using a 50 mm thick NaI scintillator coupled to a photomultiplier tube and a 1 mm ZnCdTe single pixel photon counting detector biased at 100 V.*

III. Charge-Coupled Device Detectors

Charge coupled devices (CCDs) have been used extensively for the detection of x-rays. This can be done by directly illuminating the CCD with x-rays or by converting the x-rays to visible light (via scintillators) and subsequent detection of the visible light. The coupling of scintillators is either done through fiber-optic tapers or lenses. CCDs use a serial and parallel readout scheme that can be exploited to allow one to use the CCD as a linear array with much improved time resolution. A CCD readout consists of an image transfer (parallel readout) whereby the entire image is moved down a row and the last row being shifted into the serial register, and a pixel transfer (serial readout), where each pixel is clocked out serially from the serial shift register. By masking out all but a single row of the CCD, one can clock the device in a serial mode (with no frame enable clock). Here just two clocks are sent; namely an image transfer and a serial transfer. The time resolution achieved is typically the serial clock frequency (10 MHz) times the number of serial pixels (512 to 1024). Thus several tens of thousands of row scans can be obtained with time resolutions between 50 to 100 µs/row. Alternatively, one can mask out one row near the top of the CCD and send 500-1000 image transfer pulses (no serial readout) and use the rest of the CCD as a storage device. In this readout scheme, the time resolution is on the scale 1 to 2 µs/row (with the number of single row data frames limited to the number of rows in the CCD). These two schemes described above will be utilized on station 1-BM-B.

More than one output can be used to increase the readout speed thus achieving better time resolution. We currently have 512x512 pixel CCDs with one, two, and eight outputs and a 1024x1024 CCD with four outputs. Typical read times range from 2 to 30 ms per frame. Figure 3 shows the general readout scheme for our CCD cameras. The electronics consist of a driver electronics board, CCD board, amplification and correlated double sampling (CDS) board along with digitizers and memory. The camera operates in a free-running mode with a start pulse obtained either through software or through hardware. The hardware pulse could either come from a pulse generator or a shutter that is used to prevent the camera from being exposed during readout. This way, the shutter is perfectly synchronized to the integration and readout times. A pattern generator controls the readout mode of the device (i.e., single-row readout, streak camera mode, etc.). The pattern generator uses a master clock to derive timing pulses for the CCD readout, CDS amplification, digitizer control, and memory data storage synchronization. This system allows one to change frame speeds with the click of a mouse button. An important aspect of this scheme is that it is possible to control the device using a PC and a commercial frame grabber card. Currently with a PC (128 MB of RAM and a PCI interface digital I/O card), we are able to capture 100 frames at a maximum speed of 100 frames/s. Fig. 4 shows the evolution of the flame of a match stick as it ignites as recorded with this system. The data are not noisy but rather reflect the movement of the flame around the match as it ignites. A 512-MB, two-channel, 40-MB bandwidth DRAM memory card has been designed and fabricated for high speed data acquisition by the Controls Group of the Accelerator Systems Division. It has passed all diagnostics tests and is being incorporated into the 512x512 CCD camera.

Concurrently, the electronics are being redesigned to make the system modular by means of a 3U (industrial standard) backplane into which all the boards will be connected (all electronics will be connected directly to the camera head). Within six months, the electronics will be designed and fabricated for a 1024x1024 CCD camera with four outputs that will read out at 30 to 50 frames/s. In addition to their use in time-resolved studies, the front end of the 1024x1024 device is being tested with different phosphors for both high energy applications and high spatial resolution experiments. Next year we will improve, characterize, and standardize the hardware and software. Plans are also underway for the development of a 512x512 pixel CCD camera with 16 output ports that could be read out in less than 1 ms. The present design of the electronics is modular so adding ADCs and memory channels is straightforward.

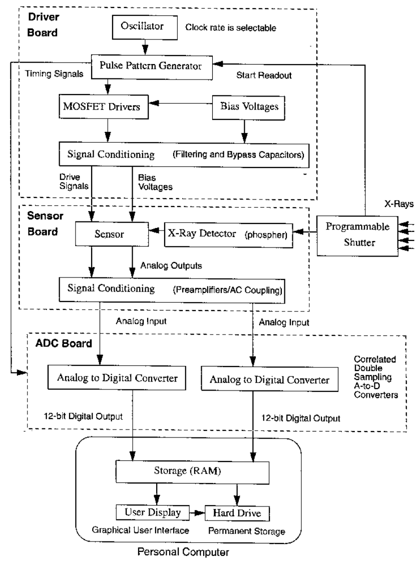

Fig. 3. Block diagram of the readout scheme for CCDs.

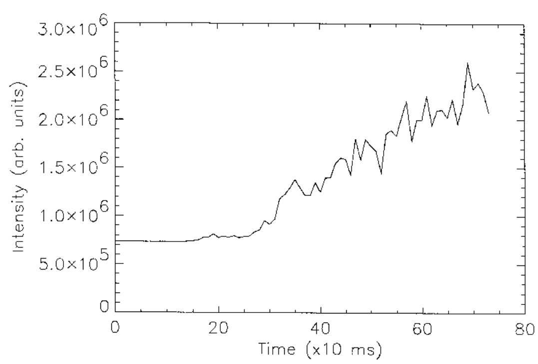

Fig. 4. Evolution of the flame of a match as it ignites.

IV. Software

Software is required to control the detectors, give real-time or pseudo-real-time information, and also be able to start/stop/initiate other devices synchronously. Currently, the CCD cameras are controlled by a PC. This stand-alone system could then easily be moved to a beamline for experimental evaluations. Concurrent to this process, the electronics needed to port it to an EPICS environment under control of a UNIX Sun workstation are being procured.

The software for the CCD cameras is a Microsoft Windows program that can be run under both Windows 3.1 and Window 95 systems in a PC with PCI bus. The software uses an IC-PCI card, a commercial image capture board, to capture the images from the cameras. The program is capable of capturing images in real time at a rate of up to 100 frames/s, displaying live images at different resolution levels, and saving captured images to the hard drive. On a 133-MHz Pentium PC from MICRON having 128 MB of DRAM, the software can capture 100 frames of real-time data. By defining a smaller active area, more frames of data can be captured. In addition, the software is designed to be user friendly, it has on-line help and supports the common Windows “Cut”, “Copy”, and “Paste” commands. The users can choose one of several modes to view the images. The images can be viewed frame by frame or continuously with different levels of resolution ranging from a single bit to all 12 bits. The software also provides programmable pulses to control the CCD camera.

Summary

Clearly, detectors do not exist that fully exploit the characteristics of the APS. We are focusing on those detectors that could be of immediate benefit to users of the APS, namely high speed and high energy applications. CCDs have demonstrated their usefulness, and we plan on continuing to use them. Currently, several manufacturers have large image formats (as many as 8000x8000 pixels) and others are designing devices that can be tiled together for large area detection. We plan on investigating such devices. We also plan on investigating the possibility of fabricating two-dimensional ZnCdTe detectors for high energy applications. We are presently in the process of fabricating a 100x100 hybrid pixel array detector. This device should be ready for testing within a year's time. As has been the case, those who want to borrow and/or collaborate, are most welcome to do so. *-Michael Hoffberg, Chuande Liu, Steve Brauer, Brian Rodricks*

Acknowledgments: The detector program collaborators are Sandor Barna (Princeton), Sol Gruner (Princeton), Dean Haeffner (SRI-CAT), Pedro Montano (BESSRC-CAT), Robert Laird (APS/ASD), Frank Lenkszus (APS/ASD), Sarvjit Shastri (SRI-CAT), John Shephard (Princeton), Mark Tate (Princeton), Robert Wixted (Princeton), Sung-Shik Yoo (Illinois-Chicago).

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2. Barna, S. L., et al., " Development of a fast pixel array detector for use in microsecond time-resolved x-ray diffraction," in *S.P.I.E. Time-Resolved Electron and X-Ray Diffraction*, Vol. 2521, 1995.

Calendar of Events

May 20-21, 1996
A Workshop on Atomic Physics with Hard X-Rays from High Brilliance Synchrotron Light Sources, Argonne National Laboratory, Argonne, IL
August 4-7, 1996
Synchrotron Radiation Satellite Meeting, Argonne National Laboratory, Argonne, Illinois
August 5-7, 1996
SPIE's 1995 International Symposium on Optical Science , Engineering, and Instrumentation.
Workshop, August 5, 6: High Heat Flux Engineering, Denver Convention Center, Denver, Colorado
Workshop, August 6, 7: Optics for High-Brightness Synchrotron Radiation Beamlines, Denver Convention Center, Denver, Colorado
August 8-17, 1996
XVII Congress and General Assembly of the International Union of Crystallography, Washington State Convention and Trade Center, Seattle, Washington

Who's New

Jonathan Lang - Asst. Physicist
Jonathan Lang, who came to us as a postdoctoral appointee, was recently promoted to Assistant Physicist. He will continue working with George Srajer in the hard x-ray polarization optics program. Congratulations!

Publications

Amiri, A., K. Vafai, and T. M. Kuzay, Effects of Boundary Conditions on Non-Darcian Heat Transfer through Porous Media and Experimental Comparisons, Numerical Heat Transfer, Part A, **27** (1995) 651-664.

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Wang, Z., and T. M. Kuzay, Thermal and Structural Analyses of Variable Thickness Plane Problems, PVP-Vol. **310**, Fluid-Structure Interaction and Structural Mechanics (1995) 135-140.